

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

## FINAL EXAMINATION

TRIMESTER 2, 2018/2019

### ETM4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS (TE)

12 MARCH 2019  
02:30 p.m – 04:30 p.m  
(2 Hours)

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#### INSTRUCTION TO STUDENTS

1. This question paper consists of 6 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

**Question 1**

- (a) A single mode step-index fiber with a core diameter of  $6\text{ }\mu\text{m}$  is designed for operation at a wavelength of  $1.35\text{ }\mu\text{m}$  has a core and cladding refractive indices of 1.39 and 1.38 respectively.
- (i) Confirm that the fiber will permit single mode transmission. [6 marks]
  - (ii) Estimate the range of wavelengths over which this will occur. [6 marks]
- (b) A step index multimode fiber with a numerical aperture of 0.2 supports approximately 1000 modes at an 850-nm wavelength.
- (i) What is a diameter of its core? [5 marks]
  - (ii) How many modes does the fiber support at 1320 nm? [2 marks]
  - (iii) How many modes does the fiber support at 1550 nm? [2 marks]
  - (iv) What percent of optical power flows in the cladding for section (ii) and section (iii)? [4 marks]

**Continued...**

**Question 2**

- (a) Consider a graded index multimode fiber that has a core radius  $a=31\mu\text{m}$ , a profile parameter  $\alpha=2.15$ , a core refractive index  $n_1=1.3$ , and an index difference  $\Delta=0.02$ . The fiber pigtail is spliced to a main transmission fiber, which has a core radius  $26\mu\text{m}$  graded index fiber with a numerical aperture of 0.19 and a profile parameter of 1.8. When the fiber axes are aligned without either a gap, radial or angular misalignment, calculate the insertion loss at the splice.

[10 marks]

- (b) A multimode has a numerical aperture of 0.32 and a core axis refractive index of 1.33 using return to zero code. The multimode optimum near parabolic profile graded index fiber has a material dispersion parameter of  $25 \text{ psnm}^{-1} \text{ km}^{-1}$  when used with a good LED source of rms spectral width 20 nm. The fiber.

- (ii) Determine the total rms pulse broadening per km within the fiber assuming waveguide dispersion to be negligible.

[12 marks]

- (iii) Estimate the bandwidth-length product for the fiber.

[3 marks]

**Continued...**

**Question 3**

- (a) A double heterojunction LED is driven by a current of 30mA to generate an internal power of 14mW. The light then emitted from the device and is coupled into a core of step index fiber with a velocity of  $2.01 \times 10^8$  m/s and critical angle at the core cladding interface  $80^\circ$ . Considering the fiber diameter is bigger than the diameter of the LED.
- (i) Determine the peak emission wavelength from double heterojunction LED when the radiative and nonradiative recombination lifetimes of the minority carriers in the active region are equal.  
[5 marks]
  - (ii) Determine the coupling efficiency and the loss in dB when the LED device is close to the fiber.  
[10 marks]
- (b) Gallium arsenide (GaAs) injection laser with refractive index 3.1 is emitting a 1203 longitudinal modes separated by 280GHz. Hence, the internal quantum efficiency of the laser is 70%. Assume that 322 photons per second generated by this laser source, and only 90% of the generated photons per second are incident on a PIN photodiode.
- (i) Calculate the number of injected electrons per second for the laser source.  
[2 marks]
  - (ii) Calculate the quantum efficiency of the PIN photodiode, in case the number of electrons generated by this PIN photodiode is 280.  
[2 marks]
  - (iii) Calculate the responsivity of the PIN photodiode.  
[6 marks]

**Continued...**

**Question 4**

- (a) Consider the design of a typical digital fiber-optic link which has to transmit at a data rate of 20Mbits/s with a BER of  $10^{-9}$  using the NRZ code. The transmitter uses a GaAlAs LED emitting at 850nm, which can couple on an average 100mw (−10dBm) of optical power into a fiber of core size 50mm. The fiber cable consists of a graded-index fiber with the manufacture's specification as follows: Attenuation ( $\alpha = 2.5\text{dB/km}$ ), intramodal dispersion,  $t_{\text{mat}} = 3\text{ns/km}$ , and intermodal dispersion,  $t_{\text{modal}} = 1\text{ns/km}$ . A silicon *p-i-n* photodiode has been chosen, for detecting 850nm optical signals, for the front end of the receiver. The detector has a sensitivity of −42dBm in order to give the desired BER. The source along with its drive circuit has a rise time of 12ns and the receiver has a rise time of 11ns. The cable requires splicing every 1km, with a loss of 0.5dB/splice. Two connectors, one at the transmitter end and the other at the receiver end, are also required. The loss at each connector is 1dB. It is predicted that a safety margin of 6dB will be required.
- (i) Estimate the maximum possible link length without repeaters. [9 marks]
- (ii) Estimate the total rise time of the system for assessing the feasibility of the desired system. [9 marks]
- (b) A 50km optical fiber with loss of 0.2dB/km and has five splices with 0.05dB losses per splice and two connectors with 0.2 dB per connector; used to transmit a data. The receiver sensitivity is  $12\mu\text{W}$ . Express the minimum transmitter power in both mW and dBm. [7 marks]

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**Appendix I**

Physical constants:

vacuum permittivity

$$\varepsilon_0 = \frac{10^{-9}}{36\pi} = 8.85418 \times 10^{-12} \text{ F/m}$$

Boltzmann constant

$$k_B = 1.38066 \times 10^{-23} \text{ J/K}$$

elementary charge

$$q = 1.60218 \times 10^{-19} \text{ C}$$

Plank's constant

$$h = 6.62617 \times 10^{-34} \text{ J-s}$$

Vacuum permeability

$$\mu_0 = 4\pi \times 10^{-7} = 1.25663 \times 10^{-6} \text{ H/m}$$

vacuum intrinsic (wave) impedance

$$\eta_0 = 120\pi [\Omega]$$

$$1\text{eV} = 1.60218 \times 10^{-19} \text{ J}$$

*Speed of Light*

$$c = 2.998 \times 10^8 \text{ m/s}$$